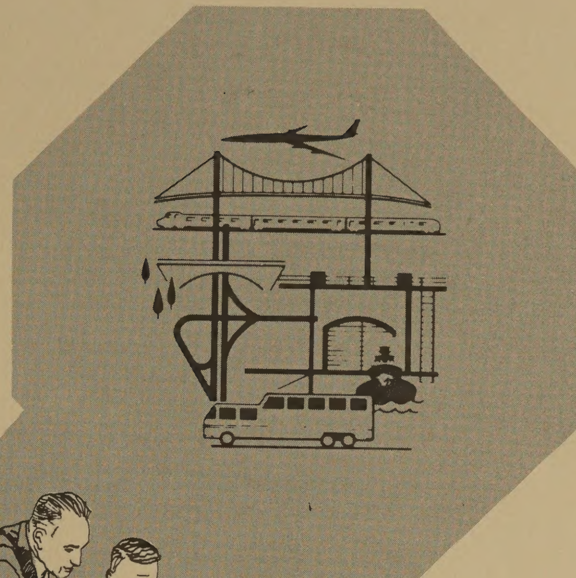
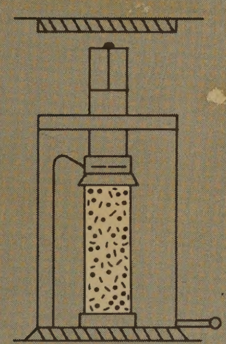
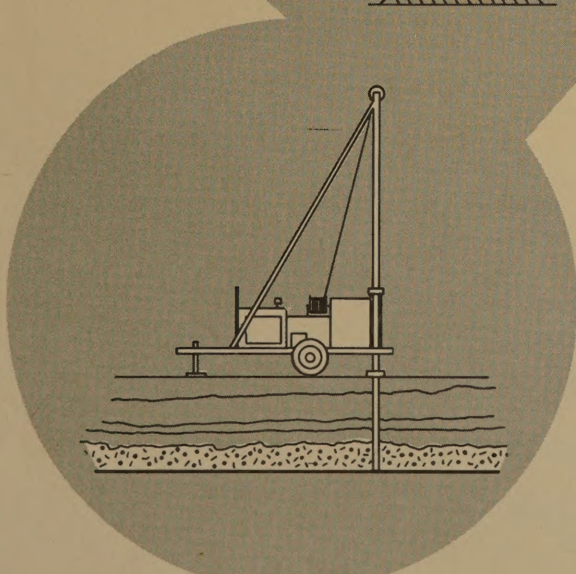
STATE OF NEW YORK
DEPARTMENT OF TRANSPORTATION

GEOTECHNICAL ENGINEERING BUREAU

AUGUST 1987







SHOULDER PERFORMANCE EVALUATION REPORT

GE 238 (2/95)

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NEW YORK STATE

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SOIL MECHANICS BUREAU

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SHOULDER PERFORMANCE EVALUATION

Introduction

On April 4, 1986, W.A. Sussman, FHWA Assistant Division Administrator, transmitted to NYSDOT an informational paper (see Appendix A) prepared by FHWA's New York Division staff documenting concerns about the adequacy of the Department's present shoulder design policy. The informational paper focused on such items as lack of sealant in the longitudinal edge joint, faulting of the joint, alligator cracking and ravelling and loss of surface material. To emphasize these items many photographs documented these conditions over a variety of shoulder sections built over a long period of time. The document or photographs do not indicate deficiencies in the structural elements of the shoulders, such as rutting or deformation, except on projects constructed in the early 1970's or late 1960's.

The Soil Mechanics Bureau has gathered information from the Department, the FHWA, and other nearby states in addition to surveying shoulders which were installed in conformance with the present Optional Flexible Shoulder specification. This investigation focused on the serviceability and life-cycle cost of present design, and the maintenance needs and resources available to meet these needs. This report is a compilation of these findings.

NYSDOT Shoulder Policy - History

The shoulder of a highway is defined by AASHTO as "that portion of the roadway contiguous with the traveled way for accommodation of stopped vehicles, for emergency use, and for lateral support of base and surface courses." [Ref. 10] The evolution of shoulder design, construction, and maintenance practices in the Department has proceeded on a rational basis supported by the field performance evaluations of many Department personnel. The Soil Mechanics Bureau has been actively involved in much of this evolutionary process because of its responsibilities for stabilized granular materials. [Ref. 2,3]

Originally, shoulders were constructed of native soil materials. As traffic conditions changed, resulting in unsatisfactory performance of these materials, it became necessary for practical reasons (safety, trafficability) to stabilize the shoulder area for improved performance. Initially, mechanical stabilization was tried. Gradation control of the granular materials used provided greater stability. In the 1950's, chemical stabilization was introduced using calcium chloride added to the granular materials. This technique was used on State highways and the NYS Thruway. Soil cement stabilization of granular materials was also tried on a limited basis on State highways.

The 1957 Department Construction Specifications introduced an item for bituminous stabilized material. Item 59W, as it was then designated, has evolved to the present Item 302.01. This item provided for the mixing in place of bituminous materials with a controlled-gradation gravel. Asphalt emulsions and cutbacks were the predominant bitumens added. A single surface treatment (a coat of bitumen covered with crushed stone) was applied as the wearing course. The 1957 book also included an item for soil cement course (Item 59Y). These items proved to be capable of providing stabilized shoulders which demonstrated significant improvements in performance over previous techniques.

The 1962 Department Construction Specifications included these same two shoulder items but technical improvements had been made that resulted in more uniform stabilized mixes which in turn resulted in improved shoulder performance. Throughout the 1960's and early 1970's, the standard specifications were improved as advances occurred in the technology. A double surface treatment was applied as the wearing course. In 1970, the Soil Mechanics Bureau, in cooperation with Regional Design, Construction, and Maintenance personnel, made a detailed field evaluation of shoulder performance in four counties. The results of that field evaluation work were reported in a 1971 report titled "The Evaluation of Shoulders in Four Counties." Several significant actions were taken based on the results of that report [Ref. 2].

- The thickness of the bituminous stabilized gravel base was reduced from 4 inches to 3 inches.
- A formal design policy was established that required shoulders to be constructed with a 3 inch thick layer of bituminous stabilized granular base material with a wearing course consisting of either a double surface treatment or 1 inch thick asphalt concrete.

It was recognized during this evaluation that the shoulder drop-off at the edge of the concrete pavement caused a significant safety problem. Maintenance procedures were developed to minimize this problem by "wedging" with asphalt concrete to fill in the drop-off and help reseal the edge joint.

The shoulder survey was conducted annually through 1978 to assess the performance of the new design policy. As shown in Appendix C, the FHWA Division Administrator did write in 1978 that the shoulder section of one inch top course and 3 inches of bituminous stabilized gravel base course provided adequate serviceability for the design life of the shoulder. The only objection raised at that time was that consideration should be given to using asphalt courses in place of the bituminous stabilized gravel.

A second report, "The Evaluation of Shoulder Performance in New York State" published in 1979, concluded that, in general, these subsequent field evaluations have shown that the shoulder policy established in 1971 provided satisfactory performance as determined by Present Serviceability Rating survey teams [Ref. 3]. It also recommended the elimination of double surface treatments as a wearing course with one inch of hot mix top course replacing it. The three inches of bituminous stabilized gravel or two inches of asphalt concrete with a one inch asphalt concrete wearing course standard was determined to be more satisfactory. This design subsequently evolved into the Optional Flexible Shoulder specification that is used today.

There were other significant findings in the 1979 report. It was noted that sections thicker than the 4 inch "standard" received lower Present Serviceability Ratings over time, although, if the shoulder was being subjected to significant traffic volume, a "full depth" design was found to be desirable from a structural viewpoint.

Second, drop-off of the shoulder was noted adjacent to many PCC pavements, as was earlier noted in the 1971 report [Ref. 2].

Third, cracking was observed in the shoulder next to PCC pavements, but it was deemed not to affect the ability of the shoulder to function as intended.

Current Shoulder Policy

The culmination of the above history is the Optional Flexible Shoulder specification which allows a contractor to provide one of five flexible shoulder options as shown in Table 1. Subbase material is placed beneath these sections to the same depth as the pavement subbase and then daylighted to the ditch or side slope.

TABLE 1 - OPTIONAL FLEXIBLE SHOULDER

	THICKNESS OF COURSES (inches)				
MATERIAL	OPTION 1	OPTION 2	OPTION 3	OPTION 4	OPTION 5
Asphalt Concrete Type 6, (Type 7 if Indicated on Plans) §401-2	1	1	1	3	-
Bituminous Stabilized Course §302-2 (opt A or C)	3	-	-	-	-
Asphalt Concrete Type 3, Binder Course, §401-2	-	3	2	-	3
Subbase Course §304-2	-	-	1	1	1

The Highway Design Manual (page 3-15) defines the areas where a "full depth" (beefed-up) shoulder is desirable. These areas are the inside of ramps, certain urban locations, and other places where the traffic is likely to stray.

This list should be augmented with field observations of locations where the traffic is now straying. It is difficult for designers to draw conclusions about the performance of existing shoulders from a field survey because performance is related to the initial construction which is highly variable. Only shoulders built in the last five years were built under the present specification, although shoulders built in compliance with that specification can be found that are fifteen years old. Areas of unusually high traffic concentrations on the shoulder are not "typical". Neither are areas where the pavement has deteriorated before its time, due to poor drainage or soils. As a result, some high traffic shoulder areas do not get the section strength they require.

Designers have the option on rehabilitation projects to carry the paving courses out across the shoulder or to design a new shoulder to be built alongside the overlay. These options have to be evaluated on a project-by-project basis because of the composition of the existing shoulder which could be almost anything ranging from native soils to a stabilized material. For the above reasons, a shoulder survey should be conducted by the Regional Soils Engineer, the results of which should form the basis for a recommendation to the designers.

There exists a need to get more shoulder expertise into our design process. The Regional and Bureau Soils Engineers are best equipped to provide this.

Department Shoulder Experience

A survey was conducted of Departmental people who are responsible for some facet of shoulders. Highway designers expressed general satisfaction with the present optional flexible shoulder specification for new or reconstructed facilities.

Construction engineers were most concerned with the ease or difficulty encountered during construction. Generally all of the asphalt concrete options are equally easy to construct. The bituminous stabilized gravel, on the other hand, is more difficult to construct because the gravel requires extra work and brings additional restrictions with it. Placement late in the year, when most pavement is laid, is hampered when the bituminous stabilized gravel is used because of curing difficulties.

The Materials Bureau has commented about the existing shoulders on pavement evaluation projects. They have noted the drop-off and cracking of ACC shoulders next to PCC pavements. They point out that PCC shoulders provide the level of quality that they find desirable.

Department Maintenance personnel were the most critical of our current practices. The Resident Engineers, our "front line" people, are not pleased with any facility that has built-in maintenance requirements and unfortunately the optional shoulder requires periodic maintenance.

The Department's Highway Maintenance Guidelines for shoulder maintenance as presently set down provide definitions and some very general guidelines. Shoulder types are defined as Sod, Granular, or Stabilized. Certain criteria for potholes, cracks, and other distortions that require repair are given for different classes of highway. These guidelines should be expanded and expounded upon.

Some interesting information surfaced during discussions with the Main Office Maintenance Division. There was no particular dissatisfaction with the present shoulder design. However, when life-cycle expenditures were mentioned, it was pointed out that the Highway Maintenance Division has no official schedule for life-cycle activities such as crack sealing and shimming to maintain a usable shoulder. Without a schedule, maintenance administrators are unable to prove a need for funding during budget hearings, resulting in a lack of funding.

This is a problem that needs to be addressed immediately. The expected life-cycle maintenance program for shoulders should be formalized to make certain that everyone involved is aware of the planned maintenance included in the life-cycle analysis (see Findings and Conclusions).

A comprehensive assessment of ACC shoulders was received from the Engineering Research and Development Bureau. Damage to asphalt shoulders adjacent to Portland cement concrete pavements falls into 2 or 3 categories. There is a general dropoff at the edge of pavement, probably due to long term densification of the asphalt concrete. There is differential frost heaving at some locations which causes the shoulder to be higher than the pavement during winter months. This heave causes the longitudinal cracking of the shoulder which occurs about 12 inches from the pavement edge. This damage occurs with both the bituminious stabilized gravel design and the full depth asphalt design.

It was noted in earlier shoulder surveys that any shoulder constructed with asphalt concrete has this damage. It occurred where the shoulder was 5 inches thick. It also occurred where up to 8½ inches of asphalt, a full pavement thickness, was constructed.

It was therefore concluded that any thickness greater than 3 inches of asphalt concrete is wasted as it offers no perceived benefit to the user.

ACC next to ACC does not have this problem. It is unique to the ACC-PCC combination.

PCC next to PCC has been refined successfully through research projects to the point where it is virtually flawless in its performance.

When possible solutions to the PCC-ACC problem were discussed with many of these experts, the concrete shoulder design was considered to be the best choice if cost were not a problem. It was pointed out that on a full-depth asphalt design the joint will open identical to the way lane widenings split off now. Full-depth also does not solve the problem of sealing the longitudinal joint.

Dissimilar materials placed side by side in a hostile environment are likely to develop flaws, no matter what the thicknesses involved are.

Field Observations

In addition to informal observations during normal travel around the state (500 miles/week), a one day tour of the Capital District area was taken with a representative of the FHWA Division Office, Jim Growney.

About 150 miles of shoulders were inspected in Region 1 on July 15, 1986. Highways mentioned in the FHWA letter were observed. The only poor sections were found adjacent to poor pavements where some systematic problem was at fault. These observations were no different than those noted in the FHWA letter. Observed were drop-off and longitudinal cracking of the shoulder in the ACC shoulders next to PCC pavements. All of these distresses occur within 2 feet of the shoulder-pavement joint, an area of great environmental stress.

Longitudinal cracking and drop-off at the PCC-ACC joint were recognized in the SMB 1971 and 1979 reports. NCHRP Report 202, Improved Pavement-Shoulder Joint Design, dealt with these problems and potential solutions in great detail. Causes for these problems are given as off-tracking of heavy trucks and, in this region, frost action.

The recently completed Pavement/Shoulder Distress Survey for portions of the Interstate Highway System done by the Technical Services Division's Pavement Management Section shows these trends. Selected portions of this information were made available through participation in a Pavement Distress/Treatment Task Force. Pavements involved are rigid and the shoulders have received some maintenance prescribed for shoulders. A review of this limited shoulder condition data shows no shoulder sections with a "Large-general" distress which would indicate a structural failure. "Small-general" distress is fairly common, indicating frequent cracking and separation.

Dropoff is "low" on newer sections (less than 10 years old) and "medium" on older jobs, indicating one to two inches of dropoff after ten or more years. A more comprehensive study of this data will be made as it becomes available and as time permits.

Observations of recently constructed Portland cement concrete pavements with asphaltic concrete shoulders were made as part of a Soil Mechanics Bureau monitoring program for bituminous stabilized material incorporating recycled asphalt pavement as the gravel.

These observations showed that for a shoulder constructed in September, longitudinal cracking became noticeable in February of the following year. This project reportedly carried little or no truck traffic that winter as the expressway sections at either end were not open. Additionally it appeared that frost action was the direct cause of the cracking as abrasions from snowplow activity are clearly seen directly over the cracks.

These observations once again verify the statements in NCHRPR 202 (Ref. 6) in the section on frost action: "Upon freezing during the first winter after construction, both the pavement and shoulder heave upward. The shoulder, however, usually heaves more than the pavement. ..... The maximum shoulder heave has been found to occur between 3 and 12 in. away from the longitudinal pavement-shoulder joint. Longitudinal cracks occur typically in the shoulder at about the point of maximum heave."

Based on the information in NCHRPR 202 [Ref. 6] this cracking occurs in all structural sections regardless of material types or section thickness (concrete shoulder excepted).

This is not to say that there are no failed shoulders in this state. There are many miles of such shoulders. All but a few of them, however, are either so old as to be years past their expected lifetime or they were built to meet an obsolete shoulder specification. Most of the surface treated shoulders are ravelled with subsequent degradation of the material underneath. Some are found to have no subbase beneath them. Some have gone without real maintenance for 25 years. The remaining failed sections are being used for climbing lanes or traffic lanes and have failed.

But, where shoulders have been built to specification and have received some basic maintenance through the years, they have performed their intended function well.

Survey of Practices in Northeast States

Other states in the Northeast were contacted and asked what their standards are for shoulder design (see Appendix D). New Jersey typically builds full depth shoulders because of anticipated use as a travel lane during maintenance. On some lower volume roads, however, a 3 or 4 inch thickness of ACC is used.

Massachusetts and Connecticut generally build the shoulder as an extension of the pavement courses. Massachusetts makes provisions for color contrast between pavement and shoulder. Both build asphalt concrete shoulders next to Portland cement concrete pavements.

Vermont built its roads with gravel shoulders. Repaved roadways now, however, are carrying the overlay out over the shoulder. This places a 1½ to 2 inch hot mix top course on the gravel. Pennsylvania builds shoulders of many types. Surface treated gravel, ACC, and PCC are all used. The ACC shoulders range in thickness from 5½ inches down to one inch.

Life-Cycle Cost Analysis

A life-cycle cost analysis was performed for the different types of shoulders built in this state (See Appendix E). Not analyzed is the full depth asphalt concrete shoulder option proposed by the FHWA. There is no way to accurately estimate the future maintenance required for that design. As can be seen on the worksheets (taken from Ref. 1), the two ACC shoulder options have roughly the same life-cycle cost. The full depth PCC shoulder, with a larger first cost, has a life-cycle cost fully two and one half times higher than the ACC options. A full depth ACC shoulder would have a similar high initial cost problem.

LIFE-CYCLE COST SUMMARY

(1985 WEIGHTED AVERAGE BID PRICES, 5% INFLATION RATE)

	Initial Cost	Total Cost at 15 years	Total Cost at 25 years	Total Life-Cycle Cost
Item 303.01 w/ACC	$ 47,200	$ 65,600	$ 69,700	$ 78,500
Item 303.01 w/PCC	$ 43,800	$ 53,500	$ 62,900	$ 63,600
PCC Shoulders w/PCC	$198,000	$200,200	$209,800	$209,800

Since, in the FHWA Technical Advisory T 5040.18 of July 29, 1982, it concludes that "The Thickness [of a flexible shoulder should] be based on an evaluation of life cycle costs and past performance under similar conditions", it appears that New York State's design is just what the FHWA was promoting in 1982.

The design proposed by FHWA's consultant, Resource International Inc., in their "Structural Design of Roadway Shoulders" (May 1986), was examined. Their design methodology is similar to the AASHTO design methodology for pavements. This method will be further studied as the Department's Pavement Engineering process is progressed.

Findings and Conclusions

The statement from the FHWA informational paper that recent construction shows problems likely to lead to early distress of the shoulders is not disputed. However, the implication that this distress precludes the shoulder from performing its function until such time as it is rehabilitated is questioned. The statement that rigid shoulders are best next to PCC pavement is acceptable if life-cycle costs so dictate. As can be seen from the foregoing, these findings are not substantially different from those in the two previous shoulder studies: both of which are summarized in the September 1979 report "The Evaluation of Shoulder Performance in New York State" [Ref. 3], pertinent sections of which are included in the appendix.

It must be remembered however, that a shoulder is for the "accommodation of stopped vehicles, emergency use, and for lateral support of base and surface courses", as defined by AASHTO.

The optional flexible shoulder specification is and has been performing adequately in New York State. It is understood that ACC shoulders are not perfect next to PCC pavement.

On very high volume roads it may be worth the extra cost to build PCC shoulders for the durability and use as travel lanes during repairs. This is a very subjective decision which will have to be made by non-technical staff. It may also be worthwhile to experiment with an open-graded crushed stone layer beneath the shoulder to the bottom of the pavement. This would prevent the subbase "dam" at the edge of pavement and may prevent some of the water problems that do occur with ACC shoulders next to PCC pavements.

There are also many miles of pavement still in service in the State where the subbase is not daylighted. The shoulders on these sections, no matter what the design may be, are generally in very poor condition. Getting daylighted gravel retrofitted to these sections is sometimes a difficult prospect but will be given emphasis in future design reviews.

Finally, sealing the edge joint is important. Dempsey and Robnett [Ref. 11] found that "Edge-joint sealing significantly reduced test sections in Georgia and Illinois." Their testing consisted of measuring flow from underdrains and comparing it to precipitation at the test sites. Edge-joint sealing should be a part of the routine pavement and shoulder maintenance.

Given these findings, there are several recommended actions believed to be worthwhile:

First, in conjunction with the Maintenance Division, a formal shoulder maintenance program for the anticipated life of an asphalt concrete shoulder must be developed.

This should include an expansion and refinement of the guidelines for shoulder maintenance activities. It is assumed in this maintenance schedule that those responsible for pavement maintenance will seal pavement cracks and joints other than the edge joint. This cost is therefore not included in this analysis. A proposed maintenance cycle is below.

LIFE-CYCLE MAINTENANCE SCHEDULE
(PROPOSED)

ACC/ACC	2 Years	Seal edge joint Fog seal
	5 Years	Seal edge joint Fog seal
	7 Years	Seal edge joint Chip & Seal
	13 Years	Pavement & Shoulder overlay
	Repeat treatment	
ACC/PCC	2 Years	Seal edge joint Fog seal
	5 Years	Wedging Fog seal
	7 Years	Seal edge joint Chip & Seal
	13 Years	Mill 1" & place 1" top
	Repeat treatment	
PCC/PCC	Seal joint every five years until overlay at 25 years. Then follow ACC/ACC Schedule.	

Second, a prototype project with several retrofitted concrete shoulder schemes should be designed and constructed to obtain cost and performance data for these activities.

Third, a research project should be initiated to investigate the viability of using open-graded subbase beneath the shoulder. This would facilitate drainage by eliminating the gravel "dam" now present in our standard section at the edge of pavement.

Fourth, the data from the Pavement Distress Survey of portions of the Interstate system in New York should be analyzed. Subsequent survey data should provide information on the service life of the formal shoulder maintenance program proposed in recommendation 1.

Fifth, there should continue to be a review of the literature to keep abreast of the state-of-the-art in mechanistic shoulder design.

REFERENCES

1. Vyce, J.M. "A Life-Cycle Cost Analysis for Asphalt and Concrete Pavements," Special Report 82 ER & DB, N.Y.S. DOT February 1985.

2. "The Evaluation of Shoulders in Four Counties" Soil Mechanics Bureau NYS DOT January 1971.

3. "The Evaluation of Shoulder Performance in New York State" Soil Mechanics Bureau N.Y.S. DOT September 1979.

4. "Paved Shoulders" FHWA Technical Advisory T 5040.18 July 29, 1982.

5. "Design and Use of Highway Shoulders" NCHRP Synthesis of Highway Practice 63 TRB August 1979.

6. "Improved Pavement-Shoulder Joint Design" NCHRP Report 202 TRB June 1979.

7. "Shoulder Geometrics and Use Guidelines" NCHRP Report 254 TRB December 1982.

8. Vyce, J.M. "Short Slab Unreinforced Concrete Pavement and Shoulders: A Five-Year Performance Summary", Research Report 95 ER & DB, N.Y.S. DOT May 1982.

9. "Thickness Design - Asphalt Pavements for Highways and Streets", The Asphalt Institute MS-1 September 1981.

10. "AASHTO Guide for Design of Pavement Structures 1986", American Association of State Highway and Transportation Officials.

11. "Influence of Precipitation, Joints and Sealing on Pavement Drainage," B.J. Demsey, Q.L. Robnett, Transportation Research Record 705, 1979.

APPENDIX

APPENDIX A

U.S. Department of Transportation
Federal Highway Administration

Memorandum

866410

Subject: Roadway Shoulder Performance

Date: April 4, 1986

From: Victor E. Taylor
Division Administrator
Albany, New York

Reply to Attn. of:

To: Assistant Commissioner
Office of Engineering
NYS Department of Transportation
Albany, New York

Earlier this year, we discussed with you our concern over the quality and performance of paved roadway shoulders in New York State. Based on observations from engineers in this office and in our Regional Office, we have received an indication that the shoulders as presently designed, constructed and maintained do not provide adequate serviceability for a reasonable time period.

We have summarized these concerns and observations in an informational paper prepared by this office. Attached is a copy of that paper with photographs.

We are raising this issue with you because we believe the NYSDOT should study and report on this matter in greater detail to determine what efforts and/or changes are needed to provide better quality shoulders. The adequacy of present shoulder designs relative to life-cycle costs should be addressed, along with the ability of these designs to provide adequate shoulder performance within the constraints of maintenance schedules and resources.

We are interested in learning your reaction to this issue and look forward to your response.

William A. Sussmann

William A. Sussmann
Assistant Division Administrator

Attachment

New York State Shoulders

Introduction

During several field trips within New York State by FHWA Region and Division Personnel, questions have arisen as to the adequacy of NYSDOT's design, construction and maintenance of roadway shoulders. There is a concern that the shoulders constructed under the Optional Flexible Shoulder Specification are not performing for an optimum period of time and that a more cost effective shoulder design, based on life-cycle costs, should be implemented.

Background

The Optional Flexible Shoulder Specification was instituted by the NYSDOT in their Engineering Instruction 80-36 dated August 8, 1980. It was to be included in all projects, except special cases, let on and after December 18, 1980.

The specification resulted from a September 1979 report done by the Soil Mechanics Bureau entitled, "The Evaluation Of Shoulder Performance In New York State". Data from 1971-79 was used in developing this report. The report found the then current shoulder design of three-inches bituminous stabilized gravel with one-inch wearing course of asphalt concrete was satisfactory. It recommended against continuing the double surface treatment wearing course and that was discontinued by the NYSDOT. It also recommended allowing the use of two inches of AC concrete in place of the three inch bituminous stabilized gravel where shown to be more economical.

Based on these recommendations, the NYSDOT developed the special specification which permitted options to the contractor. Not only was the contractor allowed to use two inches of AC, but other combinations were permitted as well. This specification was adopted as a standard specification in the December 9, 1982 Addendum No. 1 and has been incorporated in the January 2, 1985 Standard Specifications.

FHWA Field Observations

In November 1985, FHWA personnel made a field trip in Regions 4 and 5 to observe the Interstate system. It was noted that the asphalt shoulders, especially those next to PCC mainline pavement were in poor condition. The I-390 asphalt shoulders, which were six years old, had already received an asphalt wedge and seal next to the longitudinal joint and at least one chip sealcoat. The I-390 PCC shoulders, also six years old, were in excellent condition with no apparent maintenance operation necessary. The asphalt shoulders on other sections were also noted to have faulted along the longitudinal joint and developed alligator cracking in the first two to three feet next to the mainline pavement.

Past field trip reports from the FHWA Regional Office have also noted that the shoulders in New York were found to be generally in poor condition. Such

items were found as a lack of sealant in the longitudinal joint, faulting of the joint, alligator cracking and ravelling and loss of surface material.

A quick review was conducted by several of the New York Division Office Area Engineers in January 1986 to make observations of the shoulders in their Regions and to learn the impressions of NYSDOT Regional personnel concerning the Optional Shoulder Specification. The discussion with NYSDOT Regional personnel resulted in mixed reactions. Some like the Optional Specification and believed the shoulders to be performing satisfactorily. Others believed that a higher type design would improve shoulder performance and reduce maintenance costs.

It was also noted a report had been prepared by NYSDOT Region 4 personnel comparing the asphalt and PCC shoulders constructed on I-390. Because of the excellent performance by PCC shoulders, this report recommended this type of shoulder be further considered for PCC mainline projects.

Attached are several photographs taken of shoulders throughout the state which show various distress conditions. Older shoulders show the alligator cracking next to the mainline pavement and a loss of surface material. It is noteworthy that recent construction also showed problems which are likely to lead to early distress of the shoulders. On the Alternate Route 7 construction, the ACC shoulders were separated from the PCC pavement. The Cohoes Arterial showed signs of early cracking next to the mainline which have been sealed. The Route 9W project near the Coeyman's Kill Bridge also showed early cracking. Other photos are provided as examples of shoulder distress.

The FHWA New York Division Office conducted an informal survey of several states near New York to learn how their roadway shoulders were being designed and constructed. Connecticut has a variety of shoulder sections depending on the type of facility and traffic volumes. On two-lane roadways, the shoulders have 3" of ACC top and binder courses over 4" to 6" of bituminous stabilized base. On expressways, the shoulders are designed and constructed to the same section as the mainline which is 4" of ACC top and binder course over 5" to 8" of bituminous base. Both sections are on 10 to 14" of select gravel subbase. On high type roadways in New Jersey, the shoulders are also designed to the same section as the mainline pavement. Pennsylvania uses a 5/8" wearing surface on a 4" bituminous concrete base course for their shoulders on high type facilities. Vermont uses a 1¼" AC surface course over gravel subbase on all their roadway shoulders.

In New York the specifications for shoulder construction allow the contractor a choice of five options. The first three options have a 1" AC top course on either 3" of bituminous stabilized gravel, 3" of AC base or 2" of AC binder and 1" of subbase. The fourth option has 3" of ACC top on 1" of subbase. The fifth option has 3" of AC binder on 1" of subbase.

FHWA Guidelines

FHWA Technical Advisory T5040.18, dated July 29, 1982 provides the following guidelines on shoulder type selection:

> "To facilitate construction, to improve pavement performance and to reduce maintenance costs, it is recommended that the shoulder be constructed of materials similar to the mainline pavements. Rigid shoulders should be used adjacent to rigid mainline pavements. The performance of these shoulders has been superior or equal to shoulders constructed with other materials and their maintenance costs have been minimal. In addition, better mainline pavement performance is attributed to the use of these shoulders because of reduced pavement edge deflections and a tighter longitudinal joint that reduces water infiltration into the pavement structure".

The Advisory also contains guidelines on the thickness for both rigid and flexible shoulders. Rigid shoulders should be at least 6", although it may be more economical and feasible to make the shoulder the same thickness as the mainline or taper from the mainline thickness to 6" at the outside edge.

The Advisory notes that paved flexible shoulders have been designed and constructed thicker as the detrimental effects of traffic loading and the environment have become more apparent. For high volume facilities such as the Interstate system, shoulders placed to the full depth of adjacent pavements are frequently used. It concluded that the thickness of flexible shoulders should be based on an evaluation of life-cycle costs and past performance under similar conditions.

Conclusions and Recommendations:

There is concern by the FHWA that roadway shoulders designed and constructed in New York generally are not performing adequately. Corrective action by maintenance is needed (but often deferred) on many shoulders too soon after their initial construction. There are numerous examples around the state of faulted longitudinal joints between the mainline pavement and the shoulder as well as alligator cracking with resulting loss of surface material.

In view of the fact that the optional flexible shoulder specification has been in use for over five years, it is recommended that the NYSDOT investigate and report on the adequacy of these shoulder designs relative to life-cycle costs and the ability of the optional specification to provide adequate shoulder performance within the constraints of maintenance schedules and resources.

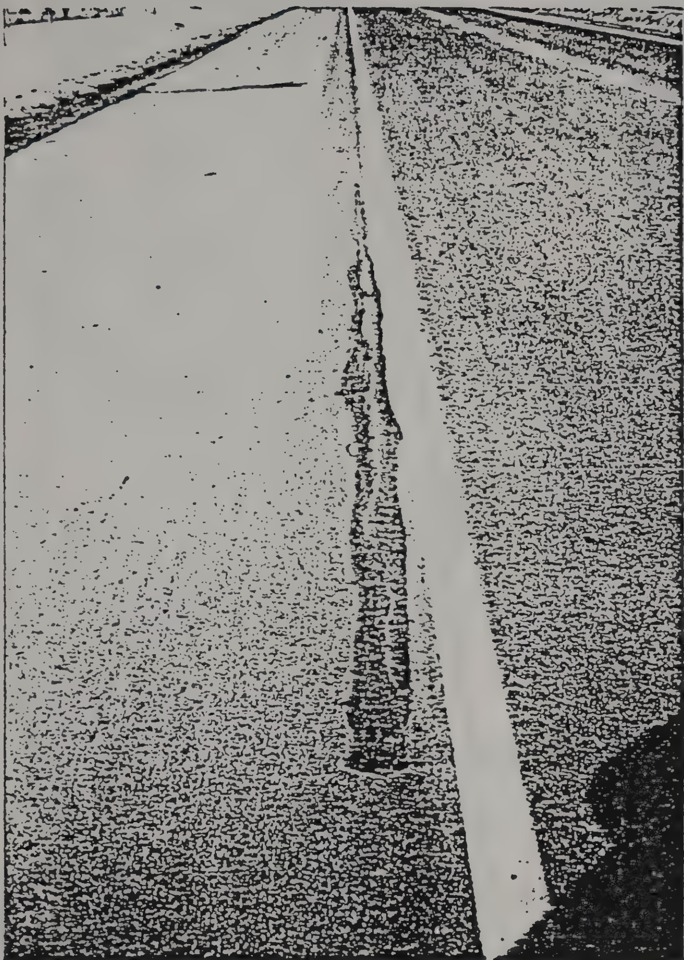

Photo 1

Albany County -- Cohoes Arterial
Right Shoulder On Southbound Roadway

Photo Taken March 3, 1986
Constructed Summer 1985

Shoulder Construction Option 3:
1" AC Top
2" Binder
1" Subbase Course

Full Depth In Selected Areas

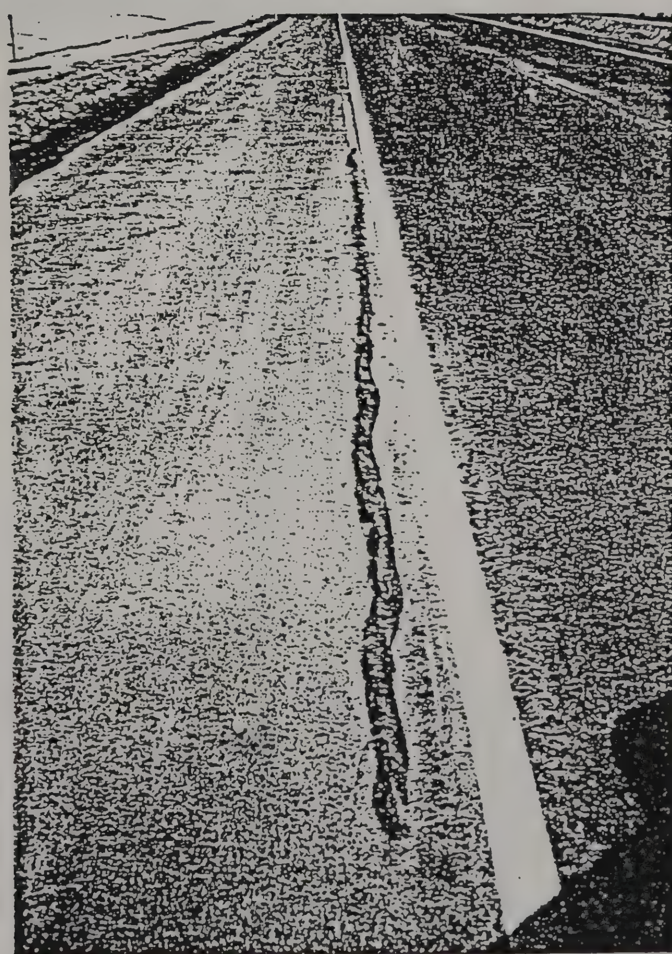

Photo 2

Albany County - Cohoes Arterial
Right Shoulder On Southerbound Roadway

Photo Taken March 3, 1986

Shoulder Construction Same As Photo 1

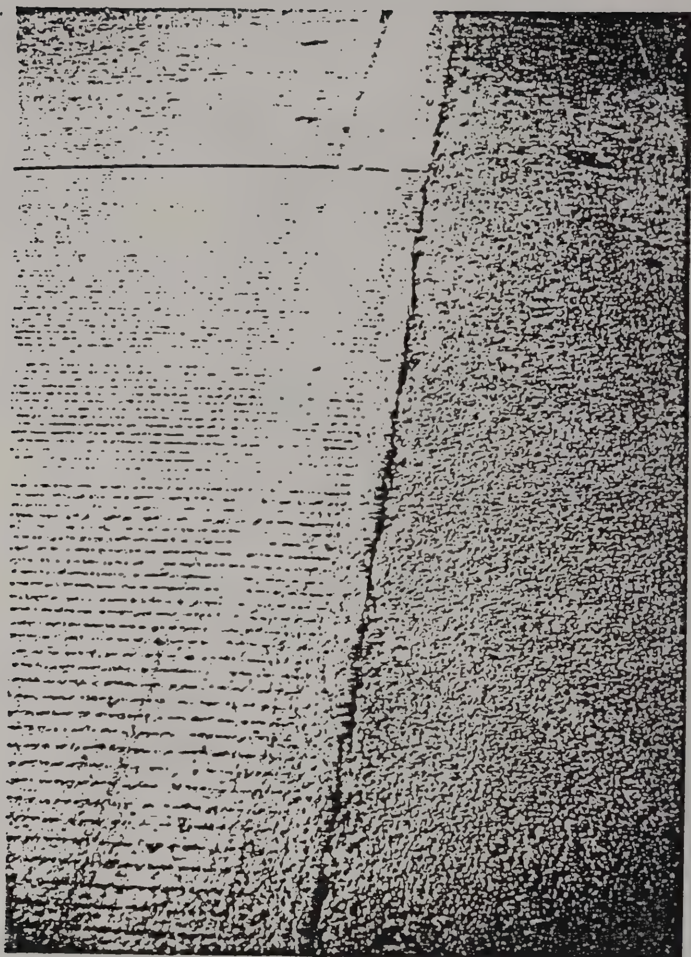

Photo 3

Albany County -- Alternate Route 7
Right Shoulder On Westbound Roadway

Photo Taken March 3, 1986
Constructed Fall 1985

Shoulder Construction Option 3:

1" AC Top
2" Binder
1" Subbase Course

Full Depth In Selected Areas

Photo 4

Albany County -- Alternate Route 7
Right Shoulder On Westbound Roadway

Photo Taken March 3, 1986
Shoulder Construction Same As Photo 3)

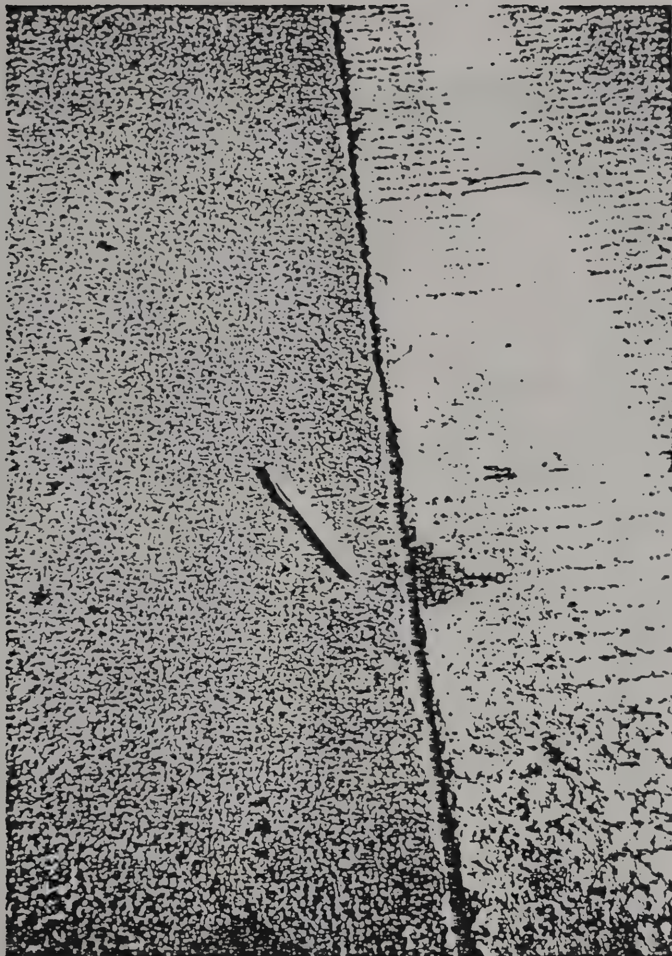

Photo 5

Albany County -- Alternate Route 7
Right Shoulder On Westbound Roadway

Photo Taken March 3, 1986

Shoulder Construction Same As Photo 3

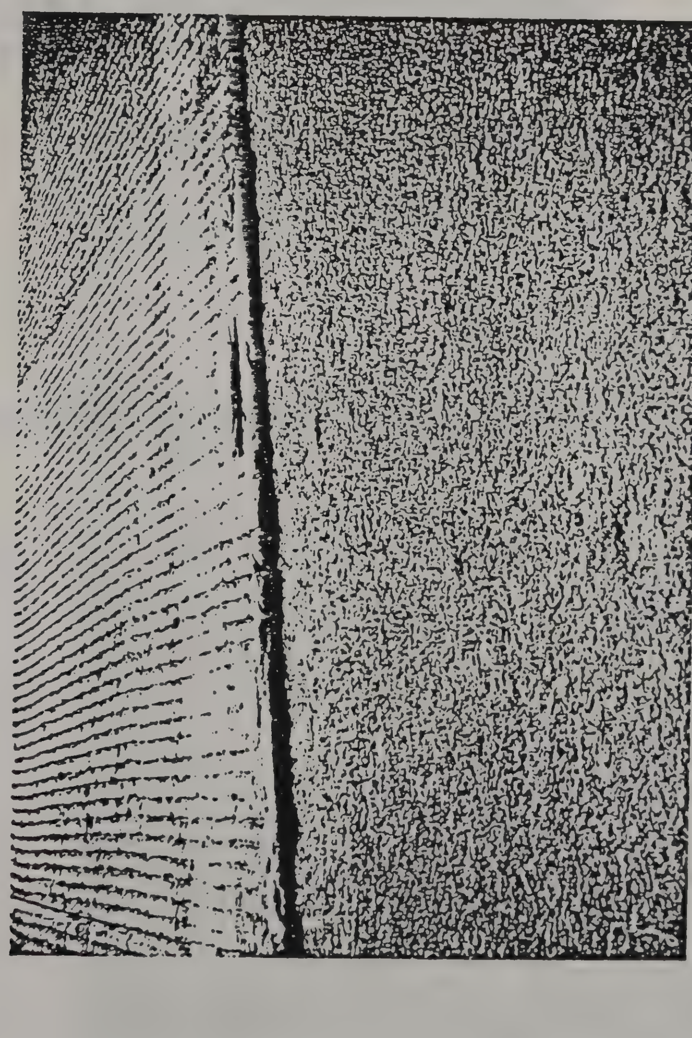

Photo 6

Albany County -- Alternate Route 7
Right Shoulder On Westbound Roadway

Photo Taken March 3, 1986

Shoulder Construction Same As Photo 3

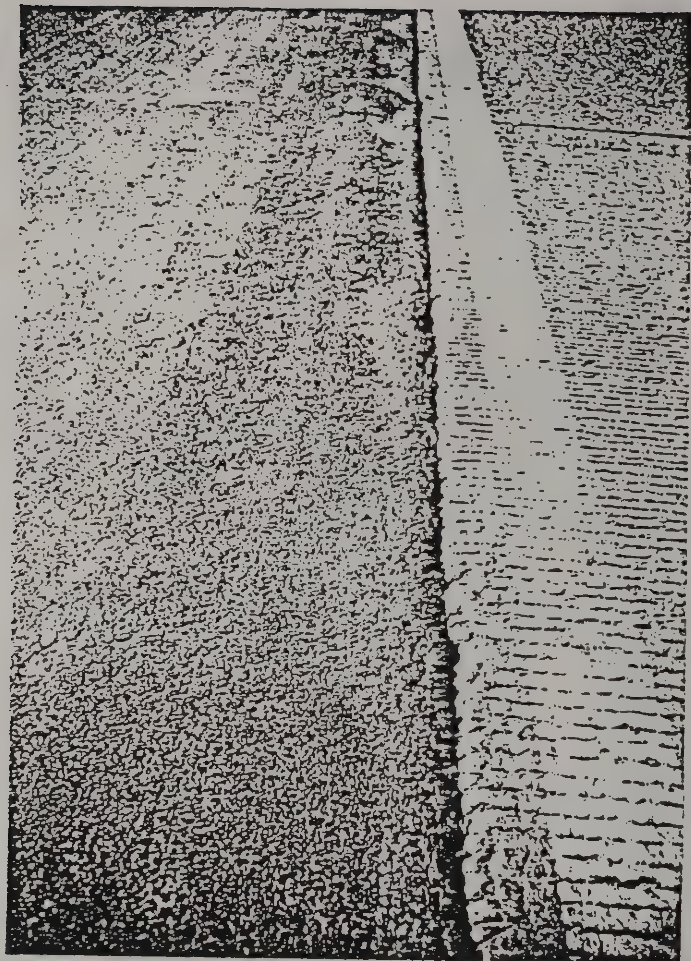

Photo 7

Albany County -- Route 7
Right Shoulder On Eastbound Roadway

Photo Taken March 3, 1986

Shoulder Construction Same As Photo 3

Photo 8

Albany County -- Rte. 9W Just South
Of Coeymans Kill Bridge

Photo Taken March 3, 1986
Constructed Spring 1985

Shoulder Construction Option 3:
1" AC Top
2" Binder
1" Subbase Course

Full Depth In Selected Areas

Photo 9

Albany County -- NYS Thruway, N. Of Exit 24, Right Shoulder on Eastbound Roadway

Photo Taken March 3, 1986
Constructed Summer 1982

Shoulder Construction Option 3:
1" AC Top
2" Binder
1" Subbase Course

Full Depth In Selected Areas

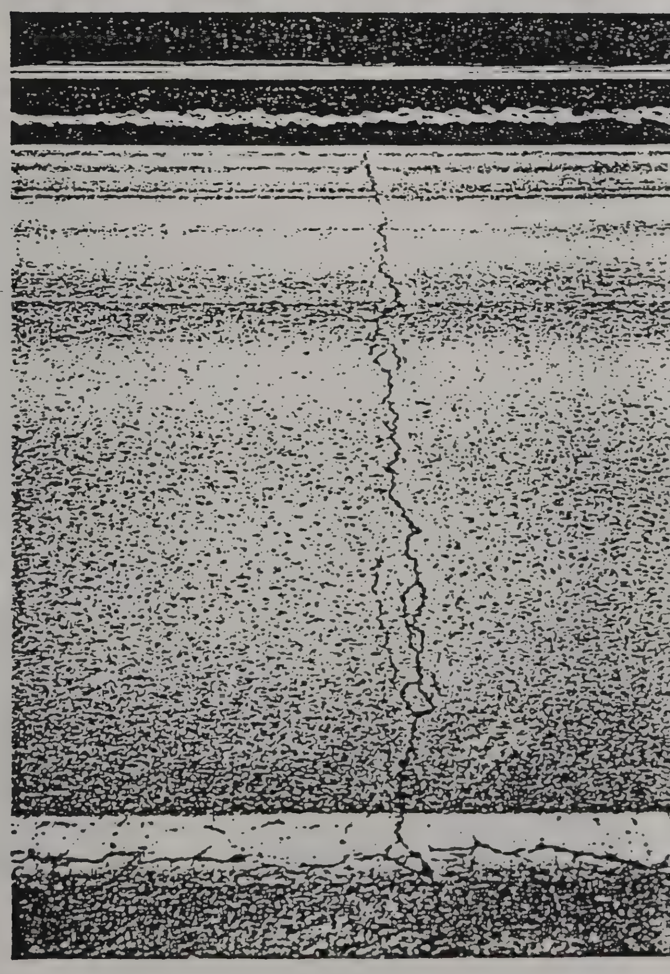

Photo 10

Albany County -- NYS Thruway, N. Of Exit 24
Transverse Crack On Eastbound Roadway

Photo Taken March 3, 1986

Example Of Transverse Cracking Of
Resurfacing Over P.C.C.

Photo 11

Albany County -- Rte. 55, Long Lane
Shoulder On Westbound Side Of Roadway
Looking West

Photo Taken March 3, 1986

Constructed Early 1970's

Shoulder Construction:
1" AC Top
3" Bituminous Stabilized Gravel

Photo 12

Albany County -- Rte. 55 Long Lane
Shoulder On Eastbound Side Of Roadway
Looking West

Photo Taken March 3, 1986

Shoulder Construction Same As Photo 11

Photo 13

Albany County -- Rte. 55
Shoulder On Eastbound Side Of Roadway
Looking West

Photo Taken March 3, 1986

Shoulder Construction Same As Photo 11

Photo 14

Albany County -- Rte. 55
Shoulder On Eastbound Side Of Roadway
Looking East

Photo Taken March 3, 1986

Shoulder Construction Same As Photo 11

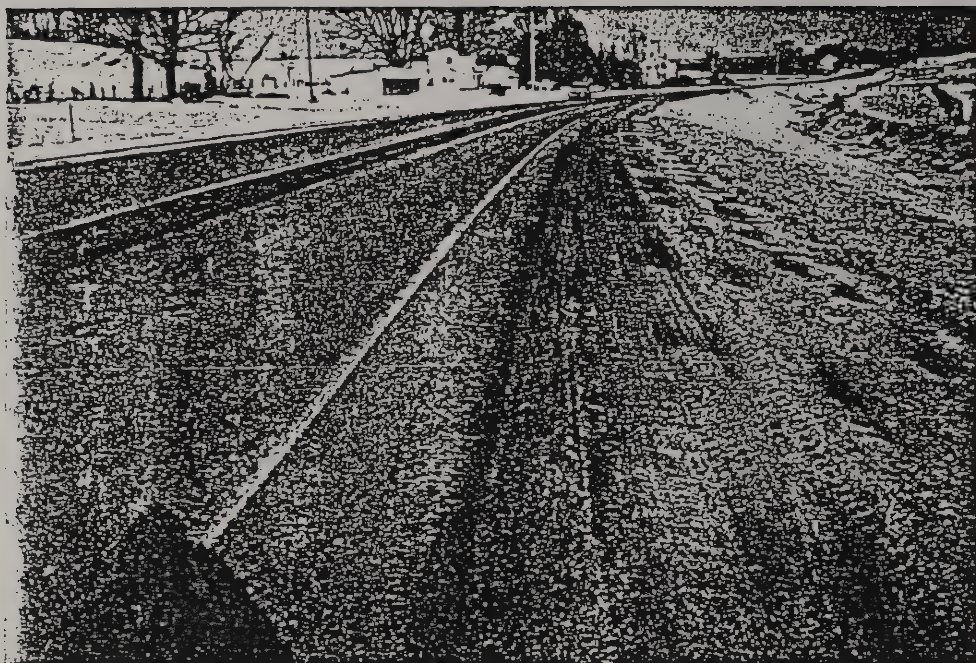

Photo 15

Route 30A Between Fonda And Johnstown, Shoulder On Northbound Side

Photo Taken January 7, 1986
Constructed Fall 1982

Shoulder Construction Option 5
3" Binder
1" Subbase

Photo 16

Route 30A Between Fonda And Johnstown. Shoulder On Northbound Side Looking South

Photo Taken January 7, 1986

Shoulder Construction Same As Photo 15

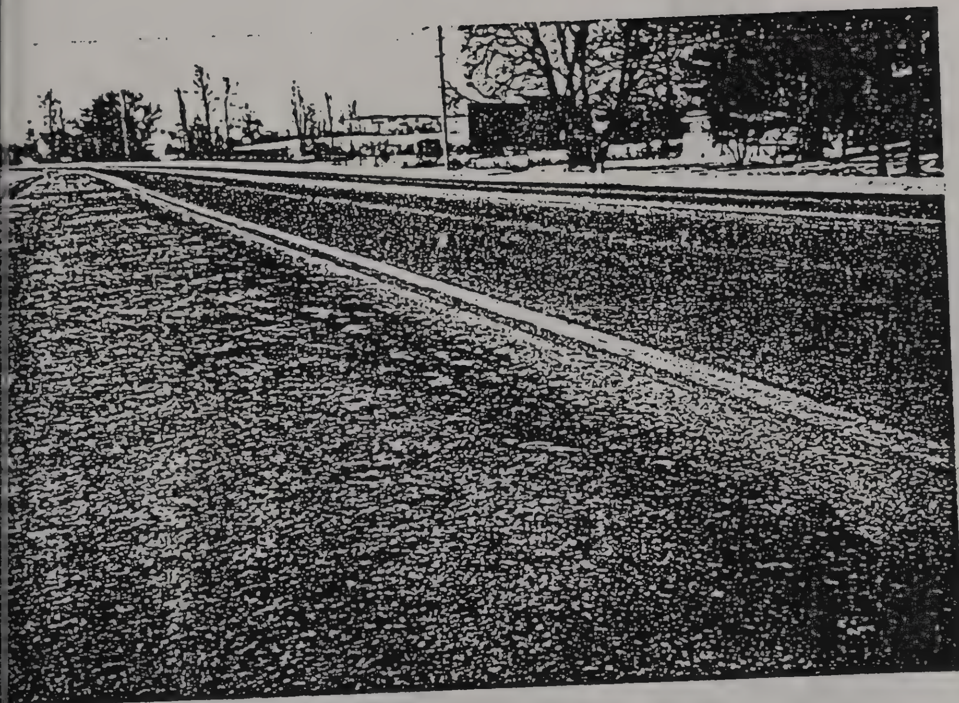

Photo 17

Route 30A Between Fonda And Johnstown

Photo Taken January 7, 1986

Shoulder Construction Same As Photo 15

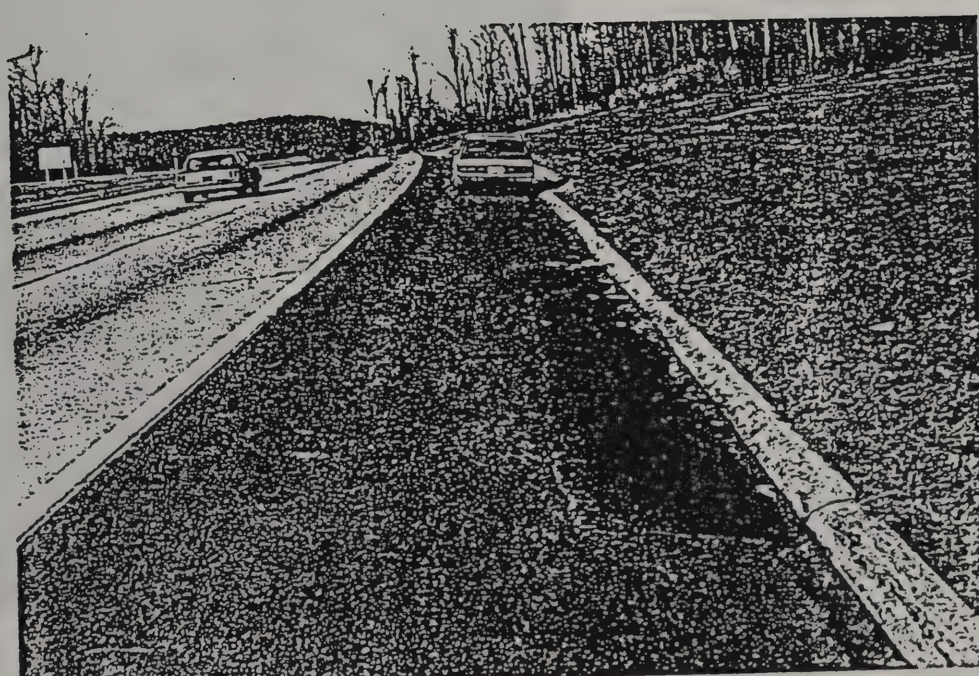

Photo 18

Sprain Brook Pkwy. Northbound Right Shoulder North Of Rte. 100C

Photo Taken Jan. 1986

Constructed Fall 1980

Shoulder Construction Full Depth:
- 2½" Top and Binder
- 8" Base
- 12" Gravel

Photo 19

Sprain Brook Parkway
Northbound Rte. Shoulder South Of
Rte. 100C, View To The North

Photo Taken January 1986

Shoulder Construction Same As Photo 18

Photo 20

Sprain Brook Pkwy.
Northbound Rte.
Shoulder South Of
Rte. 100C

Photo Taken Jan. 1986

Shoulder Construction
Same As Photo 18

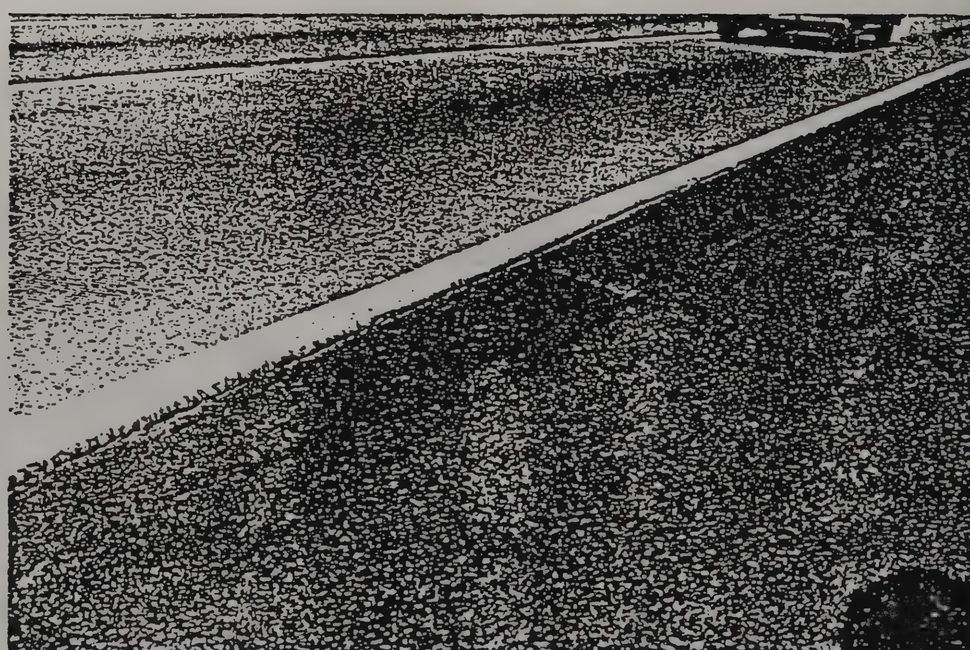

Photo 21

Route 9W -- Kingston
By-Pass, MM 1335
Right Shoulder North-
bound

Photo Taken Jan. 1986
Constructed Fall 1979

Shoulder Construction:
1" AC Top
3" Binder
12" Subbase

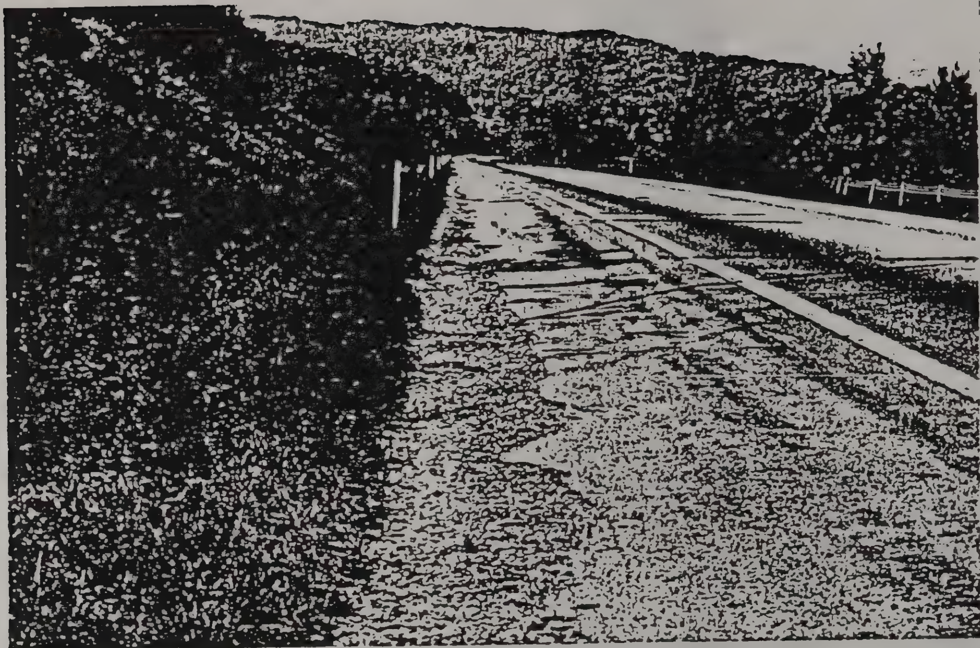

Photo 22

Region 8 -- I-84

Photo Taken Fall 1985
Constructed Fall 1970

Shoulder Construction:
1" AC Top
3" Bituminous Stabilized Gravel

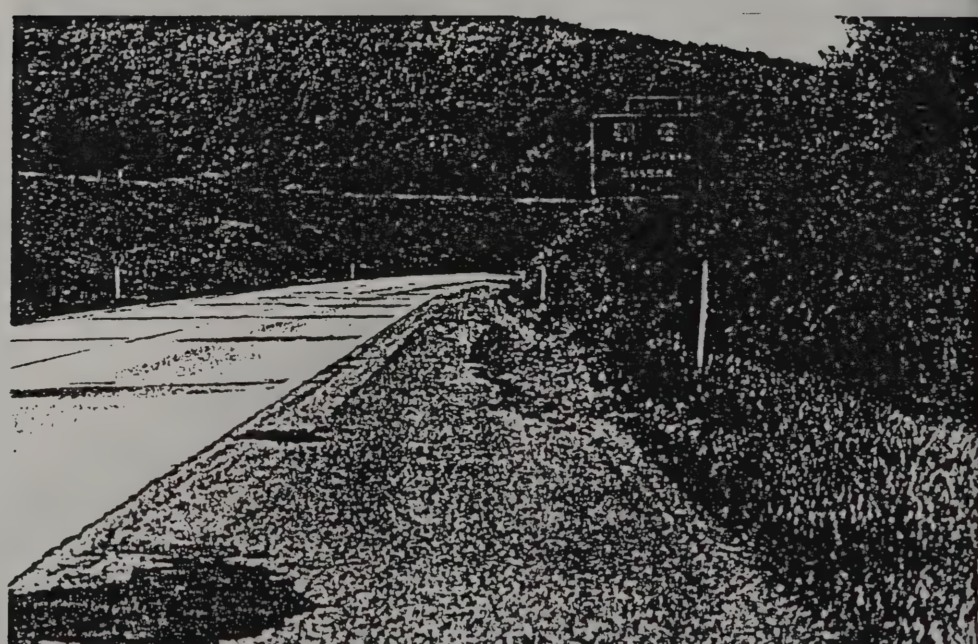

Photo 23

Region 8
I-84

Photo Taken Fall 1985

Shoulder Construction
Same As Photo 22

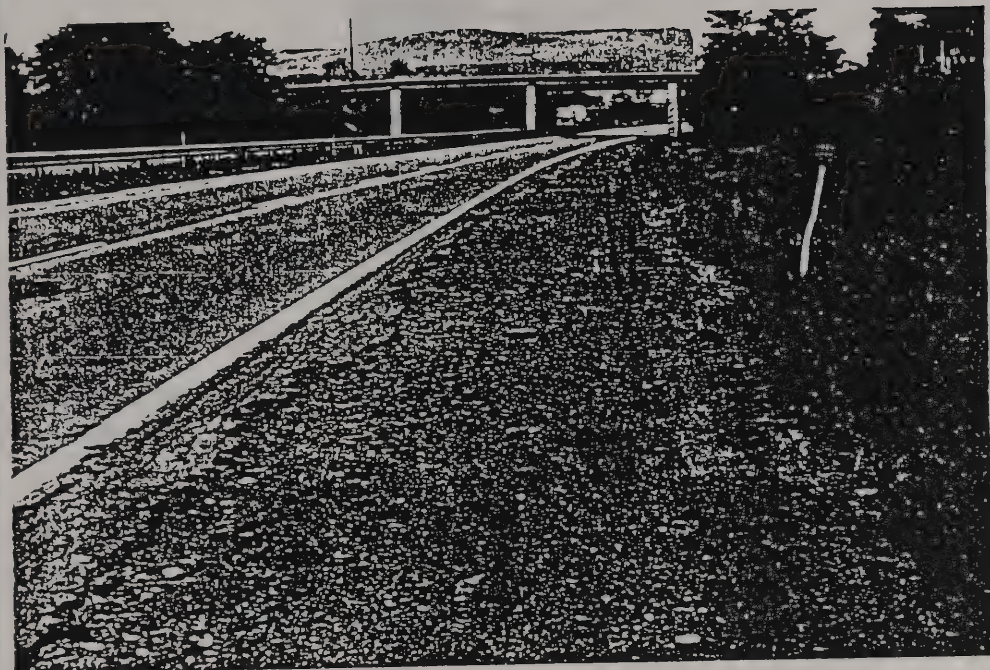

Photo 24

Region 6 -- SR-17

Photo Taken Fall '85
Constructed Late 60s

Shoulder Construction:

1" AC Top
3" Bituminous Stabilized Gravel

oto 25

gion 6 -- SR 17

oto Taken Fall '85

oulder Construc-
on Same As Photo

Photo 26

Region 6 - SR-17

Photo Taken Fall '85

Example Of Partial Shoulder Resurfacing

Photo 27

Region 6 - SR-17

Photo Taken Fall 1985

Example Of Shoulder Resurfacing

APPENDIX B

STATE OF NEW YORK

DEPARTMENT OF TRANSPORTATION

SOIL MECHANICS BUREAU

AN EVALUATION OF SHOULDER PERFORMANCE IN NEW YORK STATE

September 1979

The surveys and data collection were all conducted under the direction of Edwin Reynolds, an Assistant Soils Engineer from the Soil Mechanics Bureau of New York State. He and the Soil Mechanics Bureau wish to acknowledge the cooperation and aid extended by the Resident Engineers of the various counties and the personnel from the Regions who participated.

III. INTRODUCTION

Prior to 1971, there was no published shoulder design policy. The most frequently used design was a four inch bituminous stabilized gravel base on an adequate subbase, with a wearing course of either a single or double surface treatment. However, many shoulders were constructed using a bituminous stabilized gravel base course with a one inch asphalt concrete wearing course. A few shoulders were full depth asphalt concrete (3 or 4 inches thick).

In 1970, there was much concern for the performance of bituminous stabilized gravel shoulders with the single and double surface treatments. Maintenance costs and surface roughness which affected the safe use of the shoulder were prime concerns.

A shoulder survey limited to four counties was organized and conducted by the Soil Mechanics Bureau in 1970. The ratings were based on the Present Serviceability Rating System described in the Asphalt Institute's Manual MS-17.(1) Subsequently, a report was prepared and published in 1971 as "The Evaluation of Shoulders in Four Counties."(2) Based on that report, a Departmental design policy was issued during 1971, in the form of Engineering Instructions which are found in the Appendix. The new policy recognized that past poor performance was related to an inadequate wearing course but that the shoulder base was satisfactory.

The wearing course was upgraded to a double surface treatment adjacent to asphalt pavements with low traffic volumes and one inch of asphalt concrete adjacent to asphalt pavements with high traffic volumes and adjacent to all Portland cement concrete pavements. The thickness of shoulder base was reduced 25 percent to 3 inches.

The reduction in shoulder base course thickness from four inches to three inches was made at a time when the Federal Highway Administration was advocating thicker shoulder designs. The shoulder performance evaluation indicated that thicker shoulder designs were unnecessary and therefore uneconomical in New York State.

As a follow up to the adopted policy, annual shoulder surveys have been conducted to evaluate the performance of the shoulder wearing course designs and shoulders constructed of 2-1/2 inch to 5-1/2 inch thick asphalt concrete.

(1) "The Asphalt Institute," First Edition, November 1969, Manual Series No. 17 (MS-17).

(2) "The Evaluation of Shoulders in Four Counties," Soil Mechanics Bureau, Department of Transportation, January 1971.

X. CONCLUSIONS

Three (3) inches of bituminous stabilized gravel or two (2) inches of asphalt concrete are both satisfactory base courses for shoulders.

A one inch asphalt concrete wearing course on either of the above bases performs satisfactorily.

There is no apparent benefit to a shoulder section of asphalt concrete thicker than three inches. In fact, the ratings indicate that a thicker asphalt concrete section performs less satisfactorily. If a "shoulder" is expected to be subjected to a significant volume of traffic, it should be designed as a travel lane.

There is a drop-off of the shoulder adjacent to many Portland cement concrete pavements. Where a drop-off has occurred, Maintenance forces have solved the problem with a shimming operation. Since shimming can be done by Maintenance at a reasonable cost, the significance of this problem is not considered to be great.

The shoulder cracking problem in asphalt concrete wearing courses adjacent to Portland cement concrete pavement is of concern, but it has not required significant maintenance work.

The shoulder design policy in the Highway Design Manual is satisfactory, but can be improved by implementing the recommendations in this report.

ENGINEERING INSTRUCTION

NEW YORK STATE DEPARTMENT OF TRANSPORTATION

SUBJECT: OPTIONAL FLEXIBLE SHOULDERS

Subject Code: 7.27-1-302

bution: [A] Main Office [B] Regions [H] Special

Code: EI 80-36

Date: 8/8/80

Supersedes:

ROVED:

Deputy Chief Engineer (Facilities Design Division)

hed is a special specification, Item 15302.02 OPTIONAL FLEXIBLE SHOULDERS, which pro- for five alternative flexible shoulder systems.

tem was prepared as a result of the report "The Evaluation of Shoulder Performance in ork State" dated September 1979. This report found that the standard design consist- f three (3) inches of Bituminous Stabilized Gravel and one (1) inch of top course was rming satisfactorily. It also found that a thinner shoulder section consisting of 2) inches of asphalt concrete as a base covered with a one (1) inch thick asphalt ete wearing course performed equally well and recommended that this shoulder be allow- it was economical.

the report was published, the Department has concluded that three (3) inch thick ders consisting of either entirely dense binder or entirely top course would also be factory.

the Department's intention to allow the Contractor to make the option selection he s during construction.

t on some resurfacing jobs where the shoulders are to be constructed as extensions e pavement course or where the designer has been authorized the use of another shoul- the Optional Flexible Shoulder shall be the standard shoulder specified on all proj- starting with the letting of December 18, 1980.

ecify the Optional Flexible Shoulder item, it will be necessary to show the payment on the contract plans. This can be done on the typical sections by boxing out four deep shoulder areas, hatched or not as desired, and reference the Optional Flexible ders item on the section. The Main Office Final Plan Review Bureau will insert the fication and special note into the proposal.

WB:DMR

a (4/73)

APPENDIX C

Form FHWA 121 (Rev. 5-73)

UNITED STATES GOVERNMENT

Memorandum

DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

DATE: June 5, 1978

In reply refer to: HD-NY

SUBJECT: New York Shoulder Design

FROM: Victor E. Taylor
Division Administrator
Albany, New York

TO: Director, Soil Mechanics Bureau
New York State Department of Transportation
Albany, New York

On January 10, 1978 we wrote to the Director of Technical Services Subdivision on the subject topic. Subsequently and as a result of our meetings with your Bureau and one of our engineers observations of the annual shoulder survey in the Albany area we would like to reiterate a previous suggestion.

The annual survey is only one part of what we believe is the proper basis for specifying a shoulder design. Since the full depth hot mix and the standard (Upstate) 3" stabilized + 1" hot plant mix both provide adequate serviceability over the design life, some further attempt should be made to compare these two designs as to their total cost including maintenance over the life of the shoulder. Only when this has been done using actual maintenance expenditures can we insure that the optimum pavement design is being selected.

Our January 10 comments do not require a response. However, we would appreciate your comments and those of maintenance on the above suggestion. We are sending a copy of this letter to the Maintenance Division.

F.H. Platt

F.H. Platt
District Engineer

Form FHWA-121 (Rev. 5-73)

UNITED STATES GOVERNMENT

Memorandum

DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

DATE: January 10, 1978

In reply refer to: HD-NY

SUBJECT: Standard New York Shoulder Design

FROM: Victor E. Taylor
Division Administrator
Albany, New York

TO: Director, Technical Services Subdivision
New York State Department of Transportation
Albany, New York

Over the last few months we have discussed with Wes and Ed Moody and Ernie Lange the results of the annual surveys conducted by their staff on the adequacy of shoulders statewide. Granted, the standard 1" top course with a 3" stablized course seems to be providing an adequate shoulder for the design life of the pavement. We are still concerned, however, that from a total pavement management perspective a possibility still exists that the full depth 3" hot plant mix shoulder (Section 302-2.01 Option E) would outperform the standard shoulder from a cost effectiveness standpoint.

The data that the Soils Bureau has gathered over the last 6 years indicates that the hot plant mix shoulders are rated higher in most cases than the standard design. We suggest that some attempt be made to determine if this extra quotient of performance is worth the extra expense of construction.

In addition, we have found that average maintenance costs on the various types of shoulder are not available from the maintenance computer data base. This cost is a valuable piece of information in choosing among the types of shoulders, and some attempt should be made to acquire this data even if only on a limited sample basis. Obviously, this will require discussion with the Maintenance Division also.

If the Annual Survey of shoulders is continued we have these suggestions for your consideration:

a. Rather than getting a rating for each project by each panelist, a rating should be taken for each ¼ mile or so by each panelist and averaged. This is because it is difficult to rate for example an 8 mile long project that has scattered deterioration. This would increase our confidence in the ratings which in turn would facilitate comparisons of plant mix versus stablized (with 1" top) shoulders.

b. Rate some of the newer pavements that have been built also to see if specification changes since 1971 have had any effect on performance. This could be done at no added expense by dropping some of the old projects from the survey as they are overlaid or deteriorated below a 1.5 rating.

We will be contacting Mr. Wes Moody and the Maintenance Division in the near future to discuss these items and to get his reaction.

F. H. Platt

F.H. Platt
District Engineer

APPENDIX D

STATE OF NEW YORK
DEPARTMENT OF TRANSPORTATION
ALBANY. N.Y. 12232

FRANKLIN E. WHITE
COMMISSIONER

Wade L. Gramling
Bureau of Bridge and Roadway Technology
Roadway Management System Division
Pennsylvania DOT
Transportation and Safety Building, Room 1009
Harrisburg, Pennsylvania 17120

Dear Mr. Gramling:

The New York State Department of Transportation has been asked by the Federal Highway Administration to review its standard shoulder design. As part of our review we are inquiring of our neighboring states about their standard designs. Your name was given to us by your Chief Soils Engineer, Don Keller.

Of primary importance to us is typical sections showing your shoulder design next to both asphalt and portland cement concrete pavements. Also, we would appreciate any maintenance and life-cycle cost analysis information that you could send us on this matter, as this is where our reply to the FHWA will center.

We thank you for any information you can send us on this subject. Replies should be addressed to the above stamped address to the attention of Edward A. Fernau.

Sincerely,

WESLEY P. MOODY, Director
Soil Mechanics Bureau

By: Edward A. Fernau

Edward A. Fernau, P.E.
Associate Soils Engineer

EAF:RAB:mam

TYPICAL SHOULDER INQUIRY

SUMMARY OF SHOULDER RESPONSES

VERMONT	-	Shoulder thickness equal to pavement wearing course. Nearly 100% of state mileage is constructed of ACC. Full depth specified for inside of turns & steep upgrades with high truck traffic, curbed urban areas.
CONNECTICUT	-	Shoulder thickness same as pavement if pavement is ACC. Shoulder varies from 3" to 6" of ACC if next to PCC pavement. Engineer of Soils and Foundations may modify to suit an individual project.
NEW JERSEY	-	Shoulder thickness same as pavement for ACC next to PCC and designed per job for PCC next to PCC on all except very low volume roads. Minimum shoulder thickness is 3" or 4" (top two ACC pavement layers carried out over shoulder) full depth also specified for climbing areas, intersections & commercial areas.
MASSACHUSETTS	-	Shoulder thickness equal to pavement thickness. Peastone cover on outside shoulder serves to delineate pavement.
PENNSYLVANIA	-	Shoulder thickness varies from single surface treated gravel to full depth PCC. Each project is designed. Typical is 4" ACC base with 1" to 1½" ACC wearing course. PCC shoulders have rumble strips.

APPENDIX E

Figure 9. Costs and constants.

Item	Number	Unit Price and Item
Asphalt concrete base, Type 1	403.11	$ 36.2 ton (A)
Asphalt concrete binder	403.13	35.6 ton (B)
Asphalt concrete top, Type 6	403.16	39.5 ton (C)
Bituminous stabilized gravel	302.01	6.1 cy (D)
Portland cement concrete, Class C, reinforced	502.04	129 cy (E)
Portland cement concrete, Class C, unreinforced	502.06	115 cy (F)
Metal reinforcement for concrete pavement	502.10	2.6 sy (G)
Transverse joint supports	502.20	7.8 lf (H)
Longitudinal joint ties	502.30	2.9 each (I)
Constructing & sealing longitudinal joints	502.40	6.3 lf (J)
Constructing & sealing transverse joints	502.41	8.1 lf (K)
Asphalt concrete truing & leveling	403.21	36.3 ton (L)
Tack coat	407.01	1.8 gal (M)
Sawing & sealing overlay	18403.25	2.9 lf (N)
Pressure relief joint, existing pavement	15502.45	39.8 lf (O)
Cleaning existing pavement	633.05	.08 sy (P)
Resealing transverse joints	18502.4420	1.9 lf (Q)
Resealing longitudinal joints	18502.4425	1.6 lf (R)
Subbase course, Type 2	304.03	14.0 cy (S)
Asphalt emulsion	Maint. item	.90 gal (T)
Asphalt concrete	Maint. item (F03)	29.8 ton (U)

AADT ______ x % trucks ______ = ______ DTN

Age to first overlay = $-0.17\ (\sqrt{DTN}) + 15.955$ = ______ IF(I)

Armor coat = IF(I) + 9 = ______ IF(II)22

Maintenance unit = 0.95 (LN DTN) - 5.1 = ______ MU

Additional maintenance = 0.00072 (DTN) + 0.26 = ______ AM

Inflation rate = 5.0 %

Note: IF = Inflation factor.

Use item 303.01 for asphalt shoulders
@ $6.1/yd^2 x 5870 yd^2/mile

Prices from 1985 average bid price[s]
and represent a weighted bid price
from all 11 Regions.

Figure 10. Task costs.

1. Construction - Asphalt					
3" base course	3000 x	$	(A)/ton	= $	
1-1/2" binder	555 x		(B)/ton	=	
1" top	370 x		(C)/ton	=	
			Total (1)	= $	/lane-mile
2. Construction - Concrete - Reinforced 63'-10" slab length					
9" concrete	1760 x		(E)/cy	= $	
Longitudinal joint ties	792 x		(I) each	=	
Reinforcing mesh	7040 x		(G)/sy	=	
Load transfer devices	1000 x		(H)/lf	=	
Constructing trans. joints	1000 x		(K)/lf	=	
Constructing long. joints	5280 x		(J)/lf	=	
			Total (2)	= $	/lane-mile
3. Construction - Concrete - Unreinforced 20' slab length					
9" concrete	1760 x		(F)/cy	= $	
Longitudinal joint ties	792 x		(I) each	=	
Load transfer devices	3170 x		(H)/lf	=	
Constructing trans. joint	3170 x		(K)/lf	=	
Constructing long. joint	5280 x		(J)/lf	=	
			Total (3)	= $	/lane-mile
4. Construction - Asphalt Shoulders - Asphalt Pavement					
3-1/2"-6-1/2" gravel	815 x	14.0	(S)/cy	= $ 11,400	
3" bituminous stab gravel	490 x		(D)/cy	=	} 35,800 *
1" asphalt wearing course	165 x		(A)/cy	=	
			Total (4)	= $ 47,200	/lane-mile
5. Construction - Asphalt Shoulders - Concrete Pavement					
2"-5" gravel	570 x	14.0	(S)/cy	= $ 8,000	
3" bituminous stab gravel	490 x		(D)/cy	=	} 35,800 *
1" asphalt wearing course	165 x		(A)/cy	=	
			Total (5)	= $ 43,800	/lane-mile
6. Construction - Concrete Shoulders - Concrete Pavement					
9"-6" concrete	1225 x	115	(F)/cy	= $ 141000	
Constructing trans. joint	2640 x	8.1	(K)/lf	= 21,400	
Constructing long. joint	5280 x	6.3	(J)/lf	= 33,300	
Longitudinal joint ties	792 x	2.9	(I)/each	= 2,300	
			Total (6)	= $ 198000	/lane-mile
7. Maintenance - Asphalt - Dept. Forces					
Crack sealing	175 x		(T)/gal.	= $	
Truing, leveling, patching	110 x		(U)/ton (FOB)	=	
			Total (7)	= $	/lane-mile
8. Maintenance - Concrete 63'-10" - Dept. Forces					
Crack & joint seal	190 x		(T)/gal.	= $	
Patching, blow-up repair	20 x		(U)/ton (FOB)	=	
			Total (8)	= $	/lane-mile
9. Maintenance - Concrete 20' - Dept. Forces					
Crack & joint seal	400 x	.90	(T)/gal.	= $ 360	
Patching	10 x	29.8	(U)/ton (FOB)	= 300	
			Total (9)	= $ 660	/lane-mile

Figure 10. (continued).

10. Overlay Asphalt Pavement

1-1/2" binder	555 x	____	(B)/ton	=	$____
1" top	370 x	____	(C)/ton	=	____
Truing & leveling	370 x	____	(L)/ton	=	____
Tack coat	430 x	____	(M)/gal.	=	____
Cleaning existing pavement	7040 x	____	(P)/sy	=	____
			Subtotal	=	____
Traffic control = 0.04* x subtotal				=	____
			Total (10)	=	$____/lane-mile

11. Overlay Concrete Pavement - 63'-10"

1-1/2" binder	555 x	____	(B)/ton	=	$____
1" top	370 x	____	(C)/ton	=	____
Truing & leveling	490 x	____	(L)/ton	=	____
Saw & seal overlay	1000 x	____	(N)/lf	=	____
Tack coat	300 x	____	(M)/gal.	=	____
Pressure relief joint	60 x	____	(O/lf	=	____
Clean existing pavement	6000 x	____	(P)/sy	=	____
			Subtotal	=	____
Traffic control = 0.04* x subtotal				=	____
			Total (11)	=	$____/lane-mile

12. Overlay Concrete Pavement - 20'

1-1/2" binder	555 x	____	(B)/ton	=	$____
1" top	370 x	____	(C)/ton	=	____
Truing & leveling	490 x	____	(L)/ton	=	____
Tack coat	300 x	____	(M)/gal.	=	____
Pressure relief joint	30 x	____	(O)/lf	=	____
Clean existing pavement	6000 x	____	(P)/sy	=	____
			Subtotal	=	____
Traffic control = 0.04* x subtotal				=	____
			Total (12)	=	$____/lane-mile

13. Resurface Shoulders - 1" - Dept. Forces

	350 x	29.8	(U)/ton (FOB)	=	$10400/lane-mile

14. Resurface Shoulders - 2-1/2" - Contract

Truing, leveling, patching	75 x	36.3	(L)/ton	=	$2,700
1-1/2" binder	460 x	35.6	(B)/ton	=	16,400
1" top	310 x	39.5	(C)/ton	=	12,200
			Total (14)	=	$31,300/lane-mile

15. Resealing Concrete Joints - 63'-10" Joints - Contract

Resealing joints	1000 x	____	(R)/lf	=	$____
Traffic control = 0.04* x cost				=	____
			Total (15)	=	$____/lane-mile

16. Resealing Concrete Joint - 20' Joints - Contract

Resealing joints	3170 x	____	(R)/lf	=	$____
Traffic control = 0.04* x cost				=	____
			Total (16)	=	$____/lane-mile

17. Resealing Concrete Joint - Shoulders - Contract

	2650 x	1.6	(R)	=	$4200

18. Armor Coat - Dept. Forces

Armor coat	420 x	____	(U)/ton (FOB)	=	$____

19. Shoulder Wedging - Dept. Forces

Shoulder Wedging	90 x	29.8	(U)/ton (FOB)	=	$2700

20. Shoulder Patching

	10 x	29.8	(U)/ton (FOB)	=	$300

*In Regions 10 and 11 and Westchester County, use 0.08.

Figure 11. Life-cycle costs.

Asphalt Pavement

Pavement

(1) \$____ = \$____
(7) ____ x IF_9 ____ = ____
(10) ____ x IF(I) ____ = ____
(7) ____ x MU ____ x IF_{17} ____ = ____
(18) ____ x IF(II) ____ = ____
(10) ____ x OP ____ x IF_{27} ____ = ____
Total = \$____

Shoulder

(4) \$47200 = \$47,200
(20) 300 x IF_9 .68 = 200
(14) 31,300 x IF(I) .58 = 18,200
(20) 300 x IF_{17} .44 = 100
(13) 10400 x IF(II) .38 = 4000
(14) 31,300 x OP 1.0 x IF_{27} .28 = 8800
Total = \$78500

If pavement is 4 or more lanes, multiply total for shoulder by 0.65 = \$____

Concrete Pavement

Pavement - 63'-10" slab length reinforced

(2) \$____ = \$____
(15) ____ x IF_{10} ____ = ____
(8) ____ x IF_{17} ____ = ____
(11) ____ x IF_{26} ____ = ____
Total = \$____

Pavement - 20' slab length unreinforced

(3) \$____ = \$____
(16) ____ x IF_{10} = ____
(9) ____ x IF_{17} = ____
(12) ____ x IF_{26} = ____
Total = \$____

Concrete Pavement - Shoulders

Asphalt Shoulder

(5) \$43800 = \$43800
(19) 2,680 x IF_5 = 2,100
(13) 10,400 x IF_{10} = 6,300
(19) 2,680 x IF_{15} = 1,300
(14) 31,300 x IF_{25} = 9,400
(19) 2,680 x IF_{27} = 700
Total = \$63600

If 4 or more lanes x 0.65 = \$____

Concrete Shoulder

(6) \$198,000 = \$198,000
(17) 4200 x 5/6 x IF_{10} .51 = 2,200
(9) 660 x 5/6 x IF_{17} .36 = 200
(14) 31,300 x IF_{25} .30 = 9,400
Total = \$209,800

If 4 or more lanes x 0.65 = \$____